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THE EARTHQUAKE AND VOLCANIC ERUPTION IN GUATEMALA IN 1902.

BY

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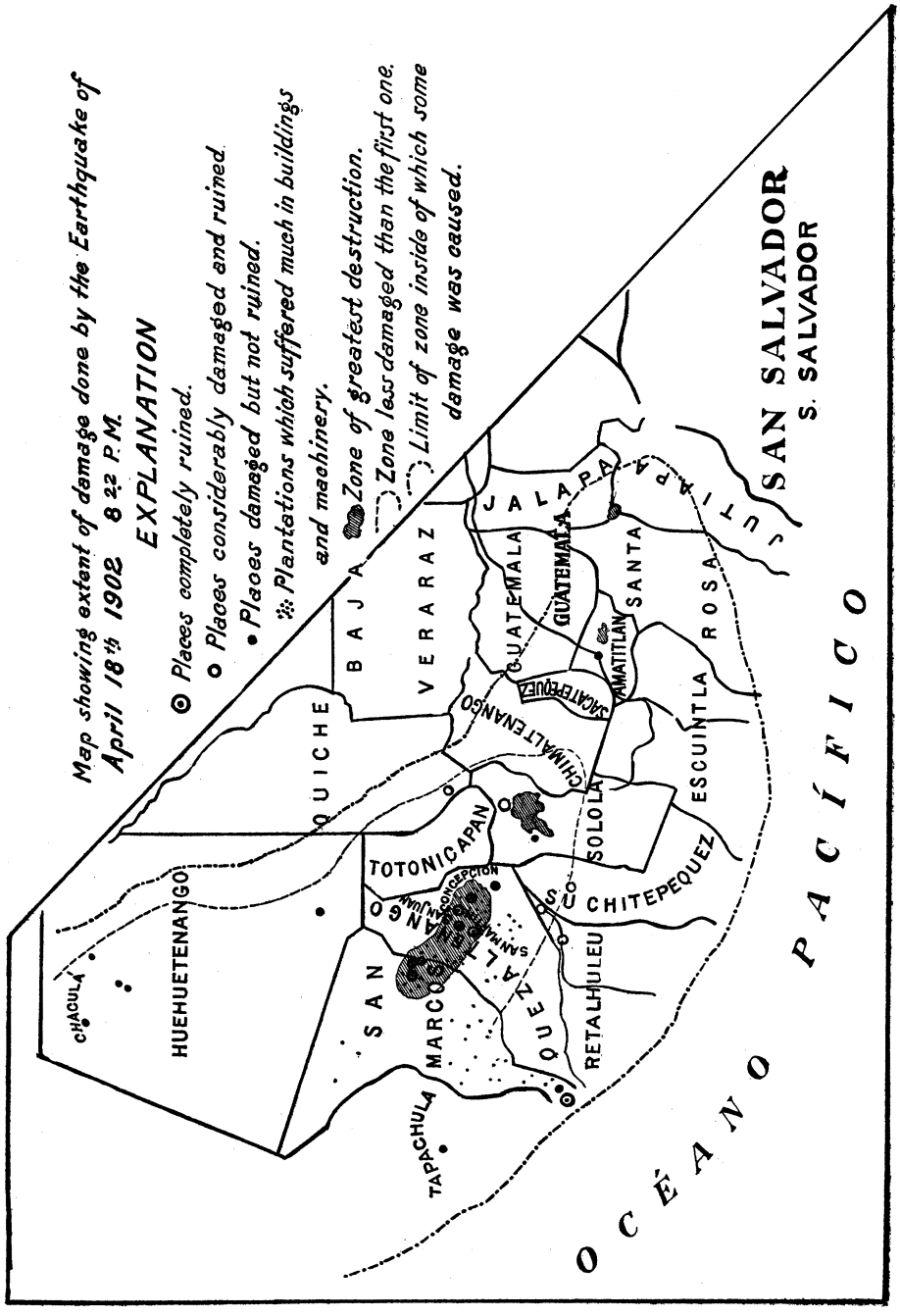
I had just arrived in Huehuetenango the day previous to the earthquake. At half-past eight in the evening of the 18th I was occupied in my room, when, suddenly, the earth began to tremble. I rushed out into the open courtyard, and was immediately joined by everyone in the hotel. The movements lasted three minutes, at first gentle, then increasing to a maximum, then declining. During the night there were smaller shocks, and others next day. These shocks were renewed in the night, and there was one tremor which lasted for fifteen minutes. This was heavy enough to cause the telephone poles to swing perceptibly for that length of time. Standing in the yard and facing the east, I could observe the swaying of our low house, the wall of which was not over 8 feet high. It appeared as if the house stood in a heavy swell of waves. There was heard only a low creaking of walls. The air was filled with dust from the fall of the church tower and a house near by, and much other damage was done. Every house in town was cracked more or less seriously. All the roofs settled, and some fell. The large tower of the Government building, square in shape, about fifty feet high and twenty feet at the base, was greatly injured, the upper part twisted so that it did not stand in line with the lower. The churches were more damaged than other buildings.

The effect of the earthquake was felt over the whole of Central America, but especially in Guatemala, Salvador, and the southern half of Mexico. The centre of destruction seems to have been in the vicinity of Quezaltenango, extending towards San Marcos. The general opinion was and is that the wave of disturbance came

from the ocean, and that the centre of the earthquake lay some hundreds of miles out in the sea. There is really nothing to indicate that the wave came from the ocean, but every reason to presume that its centre was near the centre of the greatest disturbance—that is, between Quezaltenango and San Marcos.

I visited nearly all the places which had been greatly injured. The first reports were that the towns of the western part of Guatemala had all been destroyed. There were only two larger places totally destroyed—Quezaltenango and San Marcos, and, with these, the little villages situated between them. In Quezaltenango about one-half of the houses were ruined beyond repair. These houses were situated in the lower part of the city. The upper part was less injured. All the tall buildings, with the exception of two, were so injured as to be useless, or at least dangerous. The majority of large buildings, of two or more stories, were thrown down. In many the upper story fell, while the lower remained. I was informed that only 260 persons were killed in Quezaltenango, and that altogether only some five hundred persons had been killed; but it is probable that at least 1,500 were killed in the Republic by the first shock.

In San Marcos the destruction was, if possible, greater. In the smaller villages, where the houses are made of adobe and straw, only the former were injured. All the churches in those villages, in the vicinity of San Marcos and Quezaltenango, were thrown down, only a few walls or parts of wall remaining. This destruction to churches extended over a large part of Guatemala, but especially in the western and northwestern part. There were some exceptions. For instance, in Totonicapan little damage was done. This was also the case in Quiché, where not even a house, church, or Government building was injured. But in Santo Tomas Chichecastenango, situated near Totonicapan and Quiché, the church was practically destroyed, while the adobe houses were injured by cracking. Even in the northern part of Huehuetenango district the churches were injured or destroyed, as, for instance, in San Martin, Soloma, etc. But as we go further north the damage was less. Salcachá is situated only two leagues from Quezaltenango, but it remained uninjured. The comandante telegraphed to the President that the town had been totally destroyed; but I failed to find a single house that had suffered seriously, and even the church was only slightly injured. This town lies on perfectly low and level ground along the same stream which flows by Quezaltenango. The other uninjured towns, I found, were all situated on table or


Map showing extent of damage done by the Earthquake of April 18th 1902 8.22 P.M.
EXPLANATION
⊙ Places completely ruined.
o Places considerably damaged and ruined.
• Places damaged but not ruined.
⁂ Plantations which suffered much in buildings and machinery.
Zone of greatest destruction.
Zone less damaged than the first one.
Limit of zone inside of which some damage was caused.
OCÉANO PACÍFICO
HUEHUETENANGO
CHACULÁ
QUICHE
BAJA VERAPAZ
SAN MARCOS
TAPACHULA
TOTONICAPAN
QUEZALTENANGO
CHIMALTENANGO
SOLOLA
RETALHULEU
SUCHITEPEQUEZ
GUATEMALA
AMATITLAN
SAMAYAC
ESCUINTLA
JALAPA
SANTA ROSA
SAN SALVADOR
S. SALVADOR

mesa lands, surrounded by deep barrancas or gorges, cut out by creeks or rivers. When these deep gorges were situated between the town and the earthquake centre the town had not suffered. But when, as in the case of Santo Tomas Chichecastenango, there were no barrancas to separate the houses from the earthquake centre, then destruction had taken place. This theory seemed to hold good in every instance, except as regards Salcachá. Thus Sololá was greatly injured; while Panajachel and the other villages on the Lake Atitlan were uninjured, except Santo Tomas, the latter being the only village on the lake which was not separated or protected by a channel in the direction of the greatest disturbance.

The earthquake wave seemed to have a rotary motion. Thus the stones which composed the pillars of the church in Quezaltenango and the stones of some of the pyramidal monuments in the churchyard were twisted in different directions.

On the coast the earthquake caused much damage, but not as great destruction as on the high lands. Thus, almost every coffee plantation had its machinery more or less damaged. Many houses were thrown down, and the cities San Felipe and Mazatenango suffered greatly. The map has been made for the purpose of illustrating the effects of the earthquake.

Much of the damage done to the houses is due to the poor manner of building. The stone used in Quezaltenango is very friable, and can be crushed between the fingers or under the foot. It does not harden with age. It is an andesite rock containing much hornblende, and resembles in texture a very friable sandstone. If the houses had been built of this stone exclusively very much less damage would have been done. But the manner of building is surprising. The stone is in thin slabs, about 18 inches by 6 inches by 8 inches. These stones, which are cut with a knife, are placed on end about three feet apart. In this way two narrow parallel walls are formed. The space between these walls is filled in with mud, pieces of rock, old bricks, etc. This structure then makes up the wall of the new house. The wonder is, not that such walls were thrown down by an earthquake, but that they could support themselves. The only two houses in Quezaltenango which were not injured were built solidly of the same stone. These two houses did not even show a crack from the outside.

I was told that the earthquake opened the ground in many places on the coast. I failed to find such cracks. But on the road from Zuñil to San Felipe a large part of a barranca wall was tumbled down and blocked the road for a long time. On the steep side of

the Volcan de Fuego parts of the cliffs fell along the steep barrancas. I counted some sixty places from below where large parts of the walls had been made to shed their surface covering. In one place a deep barranca had been opened, and vapours were streaming out from the interior of the volcano.

Atmospheric Phenomena accompanying the Earthquake.

There can be no doubt that the earthquake had something to do with the eruption of Santa Maria. The effects of the eruption and the earthquake extended over much of the same territory, and the centres of the two seem to coincide to an extent that could not possibly be accidental. If there had been more towns built of adobe in the vicinity of the crater it is probable that we should have found the greatest destruction of property nearer the volcano than Quezaltenango.

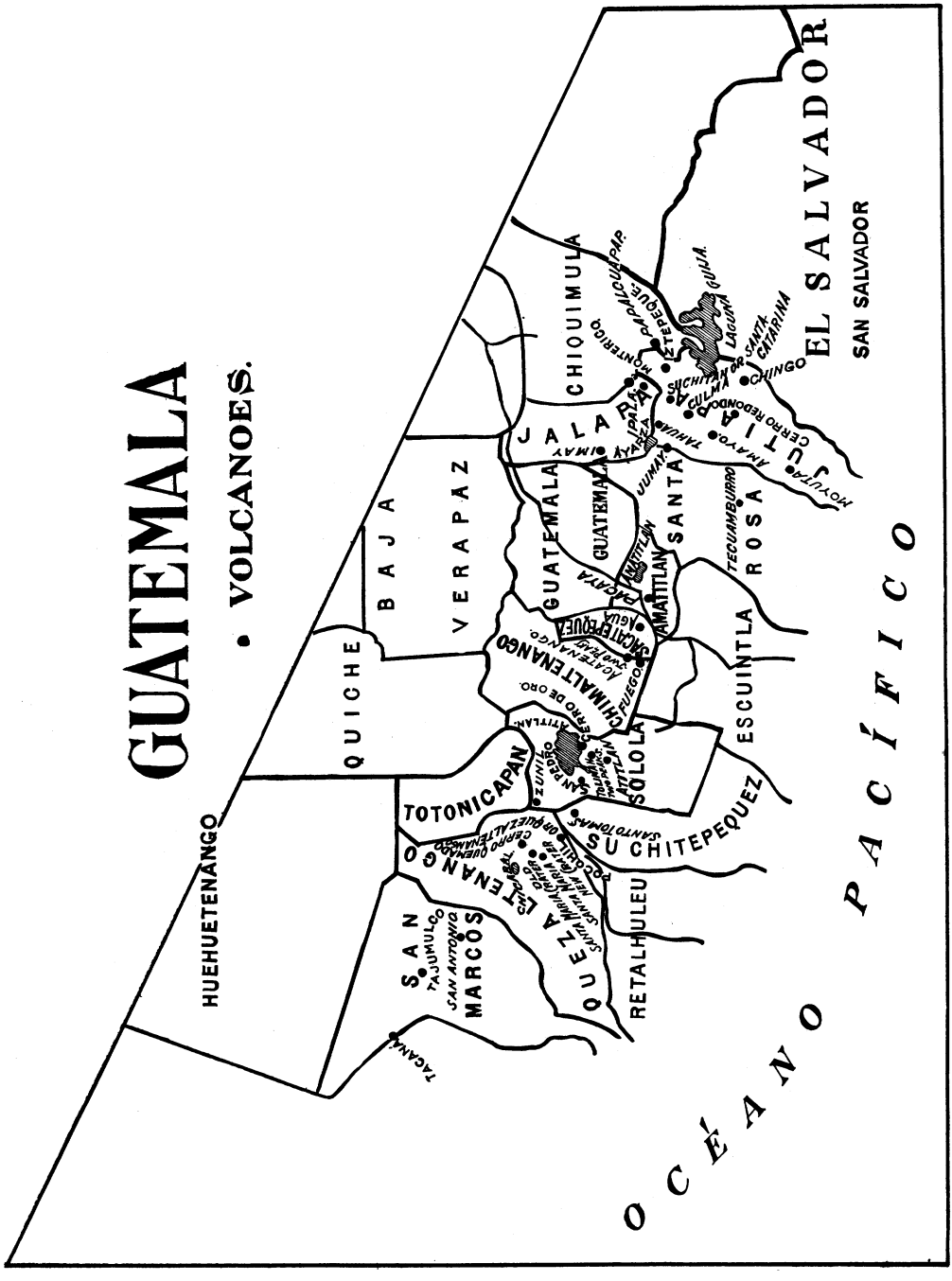
An interesting phenomenon in connection with the earthquake was the sudden cessation of rain. The regular rainy season had already set in some weeks before the earthquake, and for days before there had been rain every afternoon. But the very moment the earthquake took place the sky cleared up and there was no rain for three weeks or so. If this is not a pure coincidence, it will appear as if the earthquake was actually connected with a disturbance in the atmosphere, possibly one of electric nature, the early storms being electrical storms.

If, on the other hand, my observation that the effect of the earthquake was modified by the surface obstruction in the way of barrancas or gorges is not the result of coincidence, then it would show that in this instance, as in many others, the earthquake movement had been confined to the surface of the ground, and that it might possibly have originated through some electrical disturbance near the surface of the earth.

The Volcanoes.

The volcanic rocks in Guatemala appear to be comparatively recent, probably not later than the Cretaceous period; while the majority was ejected during Tertiary times. At the beginning of the eruptive age a large fissure appeared along the Pacific coast on a line now marked by the crest of the cordillera. Outside of this line no volcanic phenomena have left vestiges in Guatemala, as along the north and the northeast side of the Republic no traces are found of recent eruptions, and consequently of no eruptive cones. Beginning close to the boundary of Mexico, the traveller

may observe from the steamer a succession of volcanic peaks, which constitute the most characteristic, as well as the most interesting and beautiful, features of Guatemala. The one situated nearest the Mexican boundary is Tacaná, also known as Soconusco. The next in order to the southeast is Tajumulco, incorrectly called Tajumulto. This volcano, like Tacaná, presents the appearance of several broken cones. Then comes Santa Maria, the Indian name of which is Excanul. The main cone of this beautiful volcano is a perfect pyramid, from whatever side it may be seen. As appendices to this volcano must be considered the smaller eruptive craters of Cerro Quemado and possibly the Zuñil, the latter situated immediately to the southeast, while the former rises on the north side of the main cone of Santa Maria. To the east of Zuñil a smaller and irregular cone bears the name of Santo Tomas; while another in the same vicinity is known as Santa Clara. Immediately south of these volcanoes rises the regular and perfect cone of San Pedro. Next in order, and very close to San Pedro, we see the dominating pyramid of Atitlan, one of the highest volcanoes of Guatemala. On the same base as Atitlan, but hidden from the coast, are two smaller volcanoes, the larger being Toliman, with two peaks, while the smaller is known as Cerro de Oro. The latter, a very diminutive but nevertheless very perfect crater, is situated at the base of Toliman, at the very shore of the Lake Atitlan. Some thirty miles to the southeast we find the highest and most famous of the Guatemala volcanoes. The nearest one is Fuego; while adjoining, on the north side of the latter, lies the even higher Acatenango, the two rising from the same base. Separated from Acatenango by a small valley lies the majestic "Volcan de Agua," the handsomest and most regular of all the volcanoes of Central America. A short distance southeast of Agua we observe the five irregular cones of the volcano Pacaya. By following the main eruptive fissure down the coast we reach finally the volcano Tecuamburro, and further on the volcano Moyuta. The best-known volcano in this vicinity is, however, Chingo, situated on the very boundary of Salvador. All the above volcanoes, except Chingo, are situated on the main fissure, which forms the principal crest of the cordillera. North of the main fissure there exist others, the relative positions of which are not so well defined. On a short side fissure parallel with the main one we find the volcanic cones of Jumay, Cuema, Amayo, and Chingo; while Suchitán, Tahua, Papalcuapa, Iztepeque, Monterico, and Ipala seem grouped along a fissure almost running at right angles with the former. The most inland volcanoes are Imay,


GUATEMALA
• VOLCANOES.
HUEHUETENANGO
QUICHE
BAJA VERAPAZ
CHIQUIMULA
JALAPA
GUATEMALA
SANTA ROSA
ESCUINTLA
SOLOLA
CHIMALTENANGO
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RETALHULEU
SAN MARCOS
QUEZALTENANGO
EL SALVADOR
SAN SALVADOR
OCÉANO PACÍFICO

situated about midway between Ipala and the city of Guatemala, and the volcano Ticanlu, which rises about thirty miles to the northeast of Ipala. All the western volcanoes from Tacaná to Agua consist of andesite rock. The eastern group, including Pacaya, consist of basaltic rocks, except Iztepeque, which, according to Roçkstroh, is made up of obsidian or volcanic glass.

As volcanic craters we must also consider the large lakes situated immediately north of the main fissure. These lakes are, beginning with the most westerly one, Chicabay, Atitlan, Amatitlan, Ayarza, and Guija, the last partly situated in Salvador. What yet remains of the crater walls surrounding these lakes indicates that they once formed part of a chain of craters of basaltic nature, which rose on a fissure of very ancient origin. The width of the fissure was probably about eight or ten miles; while the length extended from the northern boundaries of Guatemala far beyond the borders of Salvador. Of these crater lakes the Atitlan is the one which has best preserved its original nature and form. The side walls of the lake are precipitous, especially on the northern shore, where a narrow band of debris separates the crater wall from the shore-line. The origin of Amatitlan is less apparent, and Dr. Ed. Rockstroh is inclined to consider this lake as having been formed by the rising of the volcano Pacaya. But to my mind the similarity of the two lakes is so great that it is impossible to ascribe them to different origins. Even in Amatitlan we have the precipitous crater walls on the northern sides—walls made up of basaltic rocks, like those of Atitlan. The most important characteristic of these lakes, indicating their volcanic nature, is that we can trace from them ancient lava-flows in the direction from the former summits to the present coast. These lava-flows consist of the same basaltic rocks as the craters of the lakes, and could not possibly have originated from the andesite volcanoes in their present form. This leads us to a consideration of the respective ages of the Guatemala volcanoes and the formation of the fissures.

Altitude of the Volcanoes.

The altitudes of the andesite volcanoes of Guatemala are variously given. In the geographies published in the country these altitudes are greatly overestimated, sometimes by as much as three thousand feet or more. The following list has been prepared from measurements made by the International Railway of Guatemala, by Dr. C. Sapper, by Prof. Eduardo Rockstroh, from measurements

with an aneroid by the author, and from the U. S. Government charts:*

Agua, top	12,988 feet.	Sacatepequez.	I. R.
Agua, crater	12,543 feet.	Sacatepequez.	G. E.
Amayo	3,444 feet.	Jutiapa.	C. S.
San Antonio	8,364 feet.	San Marcos.	C. S.
Atitlan, crater lake	4,425 feet.	Sololá.	G. E.
Atitlan	11,600 feet.	Sololá.	I. R.
Cerro Quemado, top	10,427 feet.	Quezaltenango.	I. R.
Cerro Quemado, crater	10,400 feet.	Quezaltenango.	G. E.
Cerro Redondo	4,155 feet.	Santa Rosa.	C. S.
Culma	3,445 feet.	Jutiapa.	C. S.
Chingo, top	5,840 feet.	Jutiapa.	I. R.
Chingo, crater	5,447 feet.	Jutiapa.	C. S.
Fuego, top	12,603 feet.	Sacatepequez.	U. S. Ch.
Ipala, top	5,477 feet.	Chiquimula.	C. S.
Ipala, crater	4,952 feet.	Chiquimula.	C. S.
Iztepeque, top	4,464 feet.	Jutiapa.	C. S.
Imay	7,216 feet.	Jalapa.	C. S.
Jumay	5,936 feet.	Santa Rosa.	C. S.
Lacandon	9,217 feet.	San Marcos.	I. R.
Santa Maria or Excanul	12,467 feet.	Quezaltenango.	I. R.
Monterico	4,329 feet.	Jalapa.	C. S.
Moyuta	5,525 feet.	Jutiapa.	U. S. Ch.
Moyuta, crater	5,280 feet.	Jutiapa.	C. S.
Papalguapa		Jutiapa.	
Pacaya, top	8,500 feet.	Amatitlan.	I. R.
Pacaya, crater	8,245 feet.	Amatitlan.	C. S.
Pocohol	9,330 feet.	San Marcos.	U. S. Ch.
San Pedro	9,917 feet.	Sololá.	I. R.
Suchitán	6,516 feet.	Jutiapa.	I. R.
Tacaná	13,329 feet.	San Marcos.	I. R.
Tahua		Jutiapa.	
Tajumulco, top	13,800 feet.	San Marcos.	I. R.
Tajumulco, crater	13,288 feet.	San Marcos.	C. S.
Tecuamburro, first top	6,064 feet.	Santa Rosa.	I. R.
Tecuamburro, second top	6,383 feet.	Santa Rosa.	I. R.
Tecuamburro, crater	4,723 feet.	Santa Rosa.	C. S.
Tolimán, southern top	10,341 feet.	Sololá.	I. R.
Tolimán, northern top	10,266 feet.	Sololá.	C. S.
Zuñil, top	11,522 feet.	Quezaltenango.	I. R.

Comparative Age of the Volcanic Fissures and Craters.

The very oldest fissure is undoubtedly the one on which are situated the crater lakes just referred to. It probably opened during the early Tertiary period. The trend of this fissure diverged more towards the east than the present coast-line, ending in the

* The initials indicate the authorities, the names Sololá, Jutiapa, etc., the Departments.

large lake of La Guija. The early craters were of gigantic nature and much larger than the later volcanoes, though inferior to them in height. From these craters flowed large lava rivers, also made up of basaltic rock fluid. The remnants of these basaltic rivers are yet to be seen in the form of numerous fantastically-shaped hills at the base of the present volcanoes, as will be presently mentioned more in detail.

After the first eruptive force of these basaltic craters had spent itself a long period of inactivity followed, during which the coast-line was gradually rising. At the end of this period, probably during the middle Tertiary, a new fissure opened along the south side of the old craters. Along this fissure opened the present andesite volcanoes extending from Tacaná to Agua. Of these more modern craters those situated most inland are, as a rule, the oldest, this being generally the case where two or more craters are situated close together on the same base. Thus we know that Fuego is younger than Acatenango; and it is probable that Atitlan is younger than Tolimán. But Cerro de Oro seems younger than both Atitlan and Tolimán, if we may judge from the preservation of its crater. From the present eruption of the new crater of Santa Maria, the San Antonio, we know that here also the new force has exerted itself towards the Pacific shore-line. Exception to this rule is the modern crater of the volcano of Quezaltenango, generally known as the Cerro Quemado. This crater opened in 1785, and at a time when Santa Maria was considered as an entirely extinct volcano.

Of the first eruptions of basaltic nature, probably from the present lakes of Amatitlan and Atitlan, there yet remain large dikes, which form a prominent part in the Guatemala coast landscape. Rising from the level slope just below the cordillera, at an altitude of about 1,500 feet, we find a series of low, precipitous hills and ridges, which, with their black, castellated rocks, stand out imposingly against the verdant slopes of the volcanoes. At first it would appear as if these ridges formed a more or less continuous belt parallel with the cordillera, but upon a closer examination this is found to be incorrect. We can follow these "peñascos" from the boundary of Mexico to that of Salvador. They rise abruptly from the plain, and are found to be in groups. The crests are often fantastically shaped, and in many instances bare of vegetation on account of their almost perpendicular sides. On the maps of the country these peñascos are nowhere marked, and in order to get a good view of them it is necessary to examine them from some altitude, preferably from the volcanic slopes. It will then be seen that,

instead of being strictly parallel to the cordillera, they actually form with it various angles, and in some instances branch out in a fan-shaped manner from the general summit of the cordillera to the plain below. This is plainly observable as regards the peñascos below Atitlan and Amatitlan, as well as those on the coast of Costa Cuca below Santa Maria and Tajumulco. As these peñascos are made up entirely of basaltic rocks, similar to those forming the walls of the two large crater lakes, etc., the only explanation of their nature is that they are remnants of the old lava-flows from the first basaltic craters in Guatemala. They can be traced from an altitude equal to that of the present crater lakes to a line drawn from below Escuintla to San Felipe—a line running parallel with the cordillera. Below this line these basaltic flows do not seem to have passed; and it is probable that at the time of their flow the ocean reached to their very base, whereas it has now receded some thirty miles below them. It is evident from the great erosion which has taken place that a very long period elapsed between the formation of these peñascos and the rising of the andesite volcanoes. The land had already then been sufficiently eroded to make it impossible for the more recent lava-flows to cover the older basaltic flows, the former simply passing by the latter. Another point of interest is that all the basaltic flows took place towards the present coast, indicating that the present continent had already risen to a great elevation long before the basaltic eruption took place.

Of the age of the eastern volcanoes little is known, and even their exact location is not marked on any map with accuracy. It seems probable that they are intermediate between the old basaltic flows and the andesite volcanoes. The volcano Pacaya seems to belong to both classes. The oldest eruptions of Pacaya consisted of basaltic rocks; while the many modern eruptions in historic times have projected both andesite lava and loose sand and ash.

Of the interior volcanoes grouped in the vicinity of Lake Guija none has been in eruption in modern times.

Eruptions in Historic Times.

According to a list communicated by Dr. Eduardo Rockstroh the historic eruptions are as follows:

YEAR.	NAME.	INTERVAL IN YEARS FROM PREVIOUS ERUPTION.	INTERVAL IN YEARS FROM LAST ERUPTION.
1526.	Fuego		
1565.	Pacaya		39
1581.	Fuego	55	16
1582.	Fuego	1	1
1585.	Fuego	3	3
1586.	Fuego	1	1
1614.	Fuego	28	28
1623.	Fuego	9	9
1651.	Pacaya	86	28
1664.	Pacaya	13	13
1668.	Pacaya	4	4
1671.	Pacaya	3	3
1677.	Pacaya	6	6
1686.	Fuego	63	9
1699.	Fuego	13	13
1705.	Fuego	6	6
1706.	Fuego	1	1
1707.	Fuego	1	1
1710.	Fuego	3	3
1717.	Fuego	7	7
1732.	Fuego	15	15
1737.	Fuego	5	5
1775.	Pacaya	98	38
1785.	Cerro Quemado		10
1799.	Fuego	62	14
1829.	Fuego	30	30
1855.	Tacaná		26
1855.	Fuego	26	0
1856.	Fuego	1	1
1857.	Fuego	1	1
1880.	Fuego	23	23
1902.	Santa Maria		22

It will thus be seen that there has been no great regularity in the eruptions, and that it is impossible to prognosticate, with hope of correctness, from former eruptions to future ones. The activity has been divided between Fuego and Pacaya. The former has during four centuries erupted twenty-two times; while Pacaya comes next in order with seven eruptions. The other three volcanoes mentioned have each but one. The following are the intervals in years between the eruptions of Fuego since 1526: 1, 3, 1, 28, 9, 63, 13, 6, 1, 1, 3, 7, 15, 5, 62, 30, 26, 1, 1, 23. Of Pacaya, the intervals have been similarly as follows: 86, 13, 4, 3, 6, 98.

If we consider the eruptions as a whole we find that the long periods of inactivity of both Fuego and Pacaya have been broken by eruptions of the one during the inactivity of the other. At no time has there been any interval of inactivity for more than thirty-nine years; while there have been eruptions in consecutive years, and twice two eruptions in the same year. Judging the future by the

past, we may say that we should not expect any period of inactivity to last longer than forty years, and that from six to twelve eruptions may be expected every century. The long periods of inactivity seem to occur about once in a century. It would also appear as if the longer intervals were succeeded by numerous smaller ones. In that case we may during the next few years expect eruptions of some volcanoes, presumably Fuego and Pacaya.

The Eruption of Santa Maria.

The 24th of October, 1902, I had just arrived at Rabinal. During the night I was awakened by what I considered to be heavy cannonading or firing of bombs. As there was to be the "Fiesta de Minerva" celebrated simultaneously in all towns and villages in Guatemala the following day but one, I naturally presumed that the festivities had begun. When I arose at daybreak I was informed that the celebration had not commenced; that the general opinion seemed to be that the cannonading proceeded from the city of Guatemala. The first outburst of the supposed firing was heard by myself about eleven o'clock at night between Friday and Saturday, October 24th and 25th. Towards morning the explosions increased in force, and continued all through the day with intervals of from one to ten minutes. Towards evening the explosions had become more loud and more frequent, and, beginning with 4.30 P.M. and continuing towards 6.30, the noise was intense and the explosions almost continuous. Already in the morning I was satisfied that one of the volcanoes had erupted, and I accordingly forwarded a telegram to my agent in Guatemala City to find out which one. The answer came only towards evening, being a negative one, as the Government prevented the circulation of news. In the forenoon I ascended the highest hill near the town, hoping to see something. The noise from the explosions was here more intense than in the valley, and the ground trembled at every detonation, when towards sunset the explosions increased in violence and it seemed as if the hill on which I stood was ready to burst. At times I had to lay hold on the rocks in order not to be thrown down, and I descended shortly after dark.

As, however, the trembling of the ground was so much less below I became satisfied that an eruption had taken place from one of the volcanoes near Quezaltenango, probably El Zuñil. Santa Maria itself had never been in eruption, and Cerro Quemado had not shown any life for one hundred and seventeen years. In the meantime a telegram had been received from the "Supreme Govern-

ment" stating that one of the volcanoes "in Mexico" had broken out and that there was no cause for alarm. This statement was not believed by any one, as the explosions came from an entirely different direction. I started the following day for Quezaltenango, but the mountain roads had become impassable through washouts [it was the middle of the rainy season], and I had to take the roundabout way over Salamá and Chimaltenango, instead of the more direct one over the mountains and Quiché. Already next day I could see from a high mountain top the immense columns of smoke, and I was able to determine that the eruption was near Santa Maria. The top of this volcano stood out against the clouds, and I presumed that the smoke issued from the mountain known as Siete Orejas, which, however, was not the case. Through one delay or the other I did not arrive in the vicinity of Santa Maria for several days. It was impossible to proceed down the coast, and I had to return to Guatemala and take the steamer to Retalhuleu in order to visit the coast region destroyed, or greatly injured, by the eruption. The following account is based upon my own observations, but I have incorporated some accounts given by one or two friends who happened to be near the volcano during the first few days of eruption.

The 24th of October, 1902, at 6.30 in the afternoon, there were suddenly heard all over Guatemala, Salvador, and the southern part of Mexico and Yucatán heavy *retumbos*, or underground explosions, so common in volcanic countries. In Mexico these *retumbos* were heard as far as Tehuantepec. In Guatemala they were heard all over the Republic, and in Flores, the capital of the Department of Peten, they sounded like heavy cannonading in the direction of Guatemala. The distance to which the sound of the explosions reached appears to have been about 400 miles, more or less. Every explosion caused heavy tremblings of the ground for at least 250 miles from the centre of the disturbance, and this trembling was much greater in the higher elevations than in the lower ones. While thus distinct on the lower plains around Salamá and Rabinal they became alarming when one ascended any of the surrounding hills. But even in the immediate vicinity of the volcano these tremblings did not take the form of earthquakes, and no damage was caused from them alone. They occurred after every explosion, and seemed to travel as fast as the explosion itself. It could be distinctly felt that they came from the same direction as the sound while one was upon the plain, but on the top of the hills the trembling movement seemed to come from the opposite direction or from beneath the ground. In the vicinity of Santa Maria these *re-*

tumbos were intensified and re-echoed from the volcano Tajumulco, so that it was almost impossible to decide upon their origin. At the time of the first *retumbos* Santa Maria was covered by a dense mantle of clouds, which was mistaken for the usual bank of rain-clouds. At about 2 A.M. on the morning of October 25th the trembling of the ground suddenly increased to such an extent that few people remained in their beds.

In Quezaltenango, situated on the northern side of Santa Maria, it was impossible to decide upon the direction of the *retumbos*, nor could any phenomenon of light be observed; but on the west side of the mountain one could clearly see, six miles away, flashes of light. These flashes of lightning extended as far as Tajumulco, and it appeared as if both volcanoes were in eruption. Later in the night, when these flashes were also seen in Quezaltenango, it seemed as if they came from the mountain known as Siete Orejas. For more than a week the people in the vicinity of the new crater did not know its location; and in the city of Guatemala, as well in the Republic generally, the place of the new crater was not known for several weeks.

At midnight, October 24–25, the obscurity caused by the cloud from Santa Maria to Tajumulco became intense, and at about 2 A.M. a fine ash began to fall over the district surrounding Santa Maria. About 9 A.M., on October 25th, the ashes changed into heavy sand of a grayish-white colour, this fall being much heavier in some places than in others. At daybreak, the 25th, there was absolutely no sign of daylight, and for a distance of 25 miles to the north, west, and south of the volcano it was necessary to use candle-light throughout that and several of the following days. With the evening of the 25th the *retumbos* diminished in frequency and intensity, and after this time they could not be heard for more than about 100 miles from the volcano. The rain of sand continued for about thirty hours, and was succeeded by a fall of mud. This began early October 26th, and continued until 6 P.M. the same day. This fall of mud did not extend as far as the fall of sand and ashes, but confined itself to a radius of 12 miles in every direction. After the fall of mud had subsided, the fall of fine sand, or rather ashes, continued throughout the days of 26, 27, 28. In the evening of the 28th the light of day began to appear, and the sky cleared to such an extent that during the night some stars became visible. On October 30th the sun could be seen through the reddish clouds of smoke, and, at the same time, it became possible to observe the eruption of smoke-clouds from the new crater. It was then seen

that, though the eruption had diminished, enormous clouds of smoke and vapour ascended to a height of about 10,000 feet above the crater and masses of ashes were thrown out about 15 miles to the west. As late as November 8th ashes fell over a district about 20 miles to the west and southwest; but the fall was light, and no further damage was then done.

During all this time the *retumbos* continued, but at longer and longer intervals, both day and night. At the end of November they had become rarer, but were heard every day. When I left Aurora, about five miles from the crater, on November 1, the noises were yet loud enough to cause much alarm, and every one was fearing a new eruption.

The electric phenomena accompanying the eruption of Santa Maria were most marked. On the 25th October, from 12 noon to 5 P.M., a sudden and most terrific hurricane swept the vicinity of Santa Maria, extending from several miles southeast of the volcano to several hundred miles west and southwest. During this time the lightning struck the ground continually, and, judging from a trip over the country after the eruption had subsided, I am inclined to think that there was not an acre that had not been struck by lightning within the territory swept by the hurricane. How far this extended north and westwards I do not know. But southwards and southwestwards I saw, for fifteen miles from the crater, trees everywhere destroyed by lightning. Branches were twisted and broken, and trunks had fallen to such an extent that progress through the woods was impossible except on foot.

While this tremendous hurricane lasted only four hours it did more damage than all the other phenomena of the eruption. It was during this time that most of the mud fell, and that all the trees for a hundred miles to the west of the volcano were stripped of their leaves.

The direct electric phenomena of the eruption consisted of flashes of lightning. From the clouds above the volcano crater a constant rain of lightning streamed down to the rim of the crater as well as to the tops of the surrounding mountains, especially to Tajumulco. These lightnings were of various colours, varying from red, pink, and violet to greenish blue.

During the night of October 24, and the day of October 25, within a radius of fifteen miles of the volcano, at short and varying intervals, electric flames or prolonged sparks were seen to ascend from the ground into the smoke and ash-filled air. These flashes had the appearance of actual elongated, narrow flames of pale violet

light, at times changing to yellowish. They proceeded from the soil in the streets, or from the open places, and reached ten or more feet in the air. There was no sound and no crackling noise, and most people supposed them to be incandescent gases ascending from the ground. In the *fincas** on the slope of the volcano I was told that when people walked on the verandas of their houses where ashes had fallen electric sparks accompanied by crackling noises would appear between their feet and the ground.

During the first four days of the eruption no view could be had of the rising crater-cloud from the immediate vicinity of the volcano. Only at a distance of forty miles to the north and east could the erupted sand and smoke be seen against the sky. The first view I had of the eruption was on the fourth day, from the hill of Vuelta Grande, and during the night-time. I could then see plainly rising from a smoky sky a dense illuminated cloud, through which flashed lightnings by the dozen in every second. Rising upwards and outwards, in the way water is thrown out of a fountain-jet, there was an almost continuous display of fire balls, which burst and threw out reddish stars.

Two days later I had another opportunity to view the eruption from a distant hill under a clear sky, and in the day. The appearance was then as follows: The peak of Santa Maria was sharply delineated against the sky. To the westward or oceanward of this pyramid rose every few minutes immense masses of globular clouds, like steam and smoke thrown out of a locomotive when it first starts. These clouds rose to a height of 20,000 feet above the crater in three or four seconds. About every five minutes the whole cloud mass was suddenly pushed to the westward, being carried over the lowlands of the coast and, probably, also northwest towards the Mexican boundary. At intervals of from a few seconds to several minutes new globular masses of clouds shot upwards from the crater, reaching the same high altitude in an incredibly short time, only again to be carried towards the ocean in the same way as at first. These cloud-masses were all white, and resembled thunder-clouds. Besides these quickly-ascending clouds there was seen a continuous reddish-yellow stratum resembling smoke, which must have been about one thousand feet in thickness and horizontally spread out at an altitude of about nine thousand feet, or about three thousand feet below the top of Santa Maria. This cloud reached east and west about twenty miles on each side of the crater. This view was had at 9 A.M. At 2 P.M. streaks of what appeared

* Farms or properties.

to be rain descended from the white cumulus clouds which every now and then rose from the crater, but from the red cloud nothing seemed to fall; it remained motionless as a stratum of reddish smoke over the land surrounding the mountain.

At the end of November, or about a month after the first eruption, I had opportunity to watch the daily eruption of clouds from the crater, especially from the hill of Aurora, on the west side of the mountain and about five miles in a direct line from the crater. This view could only be had in daytime, and then only at from 6 to 8 o'clock in the morning, after which hour the sky would cloud up so that neither the pyramid of Santa Maria nor any other part of the cordillera could be seen. Eruptions were observed only during the morning; but the general belief was that the crater erupted regularly twice a day, morning and afternoon. The fact that the volcano could never be seen in the middle of the day and in the afternoon made any reliable observation impossible; and I think it probable that the eruption continued day and night. At intervals of from a few seconds to ten minutes at the longest, columns of white smoke rose with great force from the crater. It could be clearly seen that they came from at least six distinct openings. At times six columns could be seen issuing at the same time, while a few minutes later there might be only one or two columns. At times these columns coalesced at a height of a few hundred feet; at others they remained separated to a height of two or three thousand feet. At a height of about five hundred feet above the crater, part of the issuing clouds separated from the rest, and were gradually carried along the crest of the cordillera up the coast. In this manner was formed a horizontal continuous stratum, a few hundred feet thick, but ten to fifteen miles long, extending principally in one direction, up the coast or northwestwards. The other globular clouds dissolved when reaching an altitude varying from three thousand feet to five or more thousand feet above the crater. Both the rising and the horizontal clouds were of the same whitish hue, only here and there could be seen a yellowish tint in the horizontal cloud. The issuing of the clouds at that late period after the main eruption was not accompanied by retumbos or explosions, but there were heard roaring noises, which made the earth quiver for miles. At intervals of several hours there were regular retumbos, especially in the night-time. Small shocks of earthquake took place every few days. The prevailing winds which carried the clouds away were from east to west.

From the middle to the end of November I made a more

thorough examination of the region along the coast, between Retalhuleu and Santa Maria.

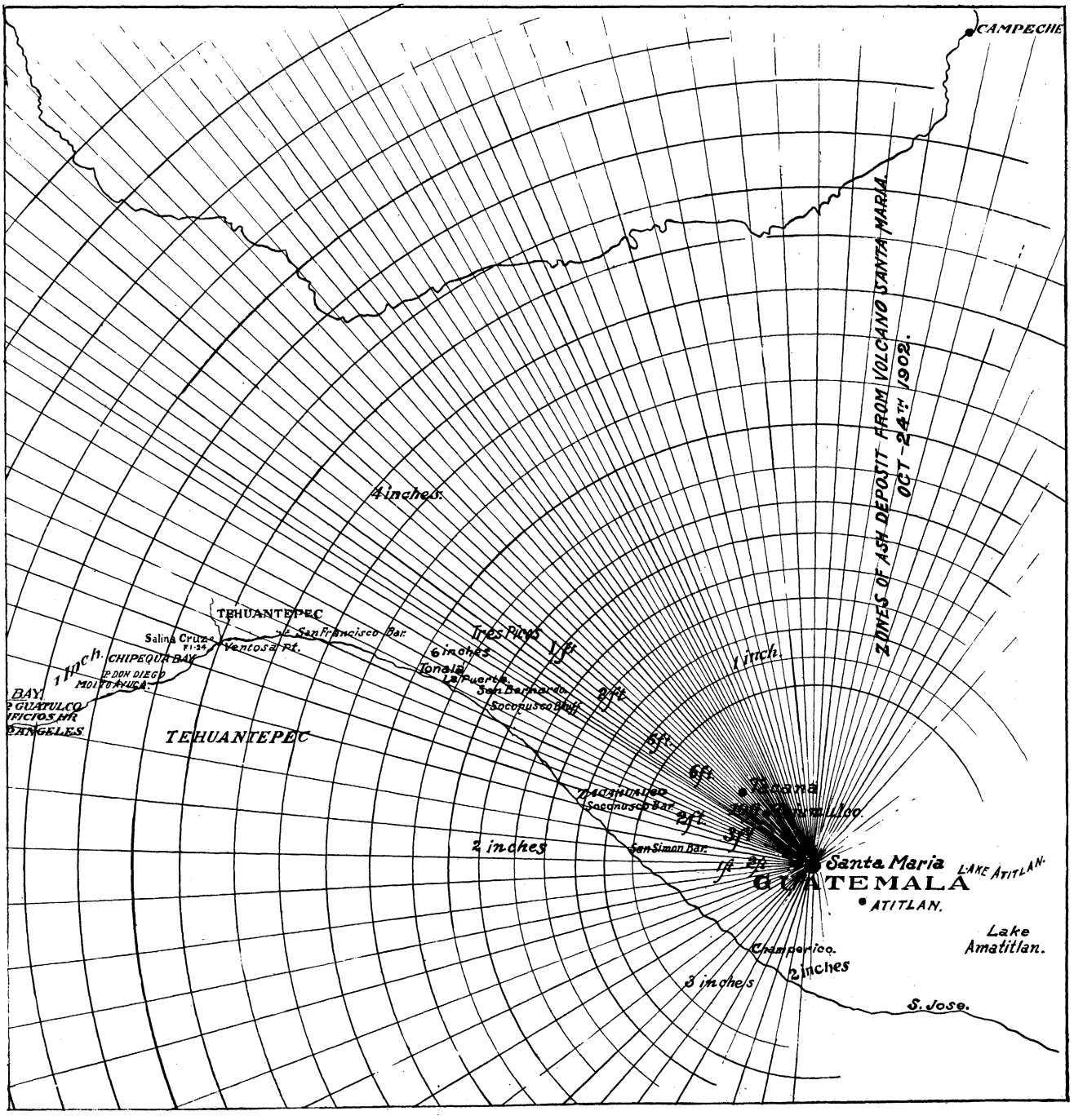
For two weeks after the eruption clouds continually hid the mountain side, but after the worst of the eruptions had ceased it was found that a new crater had opened on the southwest side of Santa Maria at an altitude of about 7,000 feet. The crater is situated immediately below the main top of Santa Maria, on a line drawn between the summit and the nearest point on the coast, and on land belonging to the finca San Antonio, so far as known. The mouth of the crater is an ellipse with the longitudinal axis running almost due east and west for about three thousand feet. The general depth of the crater is about 800 feet; while the deepest part of the crater floor is about 2,000 feet. On this main floor there are seen six funnel-shaped apertures, from which clouds of steam and sulphurous vapours constantly issue. The largest of these fumaroles is situated close to the eastern rim of the crater. It is round, and 100 or 150 feet in diameter. The other fumaroles are near the western rim of the crater. The eastern wall of the crater is nearly vertical, and reaches almost to the very top of Santa Maria. From the sides of the main volcano vast quantities of rocks were constantly falling into the new crater, with a noise resembling thunder. The side thus caving in has a depth of about 6,000 feet, and it so nearly reaches the summit that it seems likely the top cone of Santa Maria will fall into the new crater. If this happens the regular beautiful top will be replaced by two or more broken cones, like those of Pacaya and Tajumulco. Undoubtedly the largest part of the side fell in during the first days of the eruption. What has since fallen forms a cone at the bottom of the crater about 400 feet high and twice as wide. In this cone, resting against the side of the mother volcano, there is situated the sixth fumarole. The deepest part of the crater is towards the east. Towards the centre the crater bottom rises several hundred feet, but sinks again to the westward. All around the crater is a line of rocks about 800 feet wide, the rocks being partly buried, but projecting sometimes sixteen feet above the surface. The upper part of the crater consists of rocks and heavy sand; while the lower part consists mainly of light pumice-stone ash. The inner slopes of the crater form a declivity of about 60 degrees. These notes about the inner appearance of the crater are principally from a memorandum communicated by Mr. Fred. Lenzinger, who, some time after the eruption, visited the crater with two other gentlemen.

Up to the end of November the new crater had not thrown out

any lava, nor any direct streams of water. The eruption had been exclusively of sand, ashes, mud, steam, and sulphurous and other chemical fumes. During the first four days masses of sand and ash had been thrown out in a direction obliquely towards the west and northwest, or parallel to the main axis of the cordillera. Very little had been thrown to the east and south. I found the whole country covered with a thick mantle of white and gray sand. Of the tropical and impenetrable vegetation which once clothed every inch of ground which had not been previously cleared for plantations nothing was left except bare trunks and branches. As far as the eye could reach, beginning about 25 miles from the shore-line and extending to the very crest of the cordillera, was seen a continuous whitish sheet of sand, only shaded by innumerable bare trunks of trees. Here and there could be seen openings in these bare forests; these were the places where the plantations of coffee and sugar-cane had been located.

The whole country appeared exactly like a northern landscape in winter time and after a heavy fall of snow. Nothing green, nothing that would indicate the tropics, nothing that would show that the air was moist, that the temperature was high, that daily rains were thoroughly soaking the ground. The fall of the sand has been very different in different places. Along the base of the crater it had covered everything for miles around with a sheet of sand and mud about 60 feet thick. The nearest plantations were so completely hidden that it was not possible to locate the former houses. Ravines had been filled up and hollows had been levelled, while in other places immense hills had been formed by the erupted sand. In that vicinity only the larger trees could be seen above the sand sheet. Everything else was hidden below. As we proceeded farther away we found that the fall had been less, and at a distance of six miles from the crater the sand lies only from four to six feet deep, but the fall is not even. The deepest fall has been along a belt some five to six miles wide, extending from the crater hundreds of miles to the northwest, thus taking in the high upper slopes of the cordillera, but diminishing rapidly both towards the ocean and towards the interior. The extent of the fall of sand I have endeavoured to show in the map from my own observations and the reports of others. The farthest limit to which the erupted sand reached seems to have been about two hundred miles; while the lighter ashes reached as far as Acapulco and Merida, or about 550 miles.

A most striking feature of the country was the countless ditches


CAMPECHE
ZONES OF ASH DEPOSIT FROM VOLCANO SANTA MARIA.
OCT-24TH 1902.
4 inches.
TEHUANTEPEC
Salina Cruz
Ventosa pt.
1 inch.
CHIPEQUA BAY
P DON DIEGO
MOLTOAYUCA
BAY
GUATULCO
ANGELES
TEHUANTEPEC
Tres Picos
6 inches
Tonala
La Puerta
San Bachardo
Socoposco Bluff
1 inch.
2 inches
San Simon Bar.
Santa Maria
LAKE ATITLAN.
GUATEMALA
ATITLAN.
Lake
Amatitlan.
Champerico.
2 inches
3 inches
S. Jose.

or trenches, caused by the torrential rains rushing down from the hills. So furrowed was every part of the surface that we could hardly proceed six feet in any direction without having to pass a trench. The depth of the trenches varied according to location and the depth of the sand. On the slope of the crater cone some of these trenches were one hundred feet deep, not only the sand but also the original ground having been washed away. But at a distance of four or more miles we found no trenches deeper than six feet, while the majority varied from a few inches to several feet. To traverse such a ground was exceedingly laborious, it being a continuous jumping across the thousands of gullies and a continuous crawling up one bank and down another.

The effect of this washing out or early erosion can easily be imagined. Where formerly ran small brooks the bottom between the hills now formed irregular flats, upon which the water had spread as a thin sheet. But the greatest change had taken place in the largest rivers. The rivers Samalá, and Ocojíto had in places completely changed their course, cutting through and overflowing their banks, which had been partly, or even entirely, washed away. In most places the banks had been denuded of their trees for hundreds of yards inland, and the underlying boulders had been laid bare. The river-beds had been deepened some thirty feet, and widened in many places to twice their original size.

Almost every afternoon the rivers rose as much as thirty feet above their former high-water mark, carrying not water, as formerly, but a thick gruel-like mud, consisting of water, sand, ashes, and boulders. The aspect of these terrific torrents sweeping everything before them was something frightful. In the rushing waters were seen a mixture of trees, dead cattle, boulders, sand, broken limbs of trees, the whole roaring with the noise of distant thunder, and it was generally feared that the whole aspect of the river system would be changed, as, for instance, at the mouth of the River Ocos. The general opinion was that this mass of mud was thrown out of some opening in or below the new crater, and was not due to rains. But I am satisfied that this is not the case. Nearly all the barrancas in the upper part of the cordillera had been covered with from six to twenty feet of ashes and sand. If we remember that many of these barranca walls are almost perpendicular, and that daily torrential rains, lasting five or six hours, swept these accumulated masses of sand and ashes down in the former river-beds, we can easily understand that new outlets had to be formed. Much of the matter ejected from the crater consisted of pumice-stone, which,

on account of its lightness, remained on the surface of the flood-waters, and tended to block the narrow outlets of the gulches. To the mud, stones, and ashes, were added masses of broken limbs or trunks of trees, all at times closing the outlets in the barrancas, and backing up the flood-waters high above any former mark. Hundreds of such flood-lakes would then, perhaps, give away at the same time, and with renewed force be carried further down the rivers. As a consequence, all the smaller and most of the larger bridges were swept away during the third and fourth days of the eruption. They were later being replaced by wires strung over the torrents, and one could pass over suspended in a cage. Other bridges were being replaced by hammocks, over which the not too timid traveller could pass.

Nature of the Erupted Material.

The nature of this material differs somewhat with the locality. At a distance of five miles from the crater the lowest layer consists of white sand mixed with pieces of pumice-stone. This layer seems to occupy four-fifths or five-sixths of all the erupted mass. The upper one-fifth consists of bluish-gray sand of more uniform nature and of finer grains than the lower layers. In this darker deposit there is less pumice than in the lower layer. The upper part of the darker layer contains finer sand than the lower part, and has the appearance of well-mixed coarse mud. There is every reason to believe that the mud resulted from the mixing of sand and rain in the air and was not thrown out as mud from the volcano. It is evenly distributed, and the layer is sufficiently solid to support a mounted rider, the horse's hoofs leaving but little impression. The solidity of this upper layer is due to the fineness of its particles and their being packed by water. On the top of this darker layer fell several inches of light-coloured ash.

Within a radius of ten to twelve miles of the crater there fell also numerous stones. On the upper edge of the crater lies a belt of bluish finely-grained rock, about 800 feet in width. The blocks are large, weighing many tons each. Farther away from the crater the blocks are replaced by angular stones, from the size of a fist to that of a hazel nut. Some are finely grained, of a bluish colour; others contain large crystals of hornblende in a light-coloured matrix. The former resemble basalt; while the latter appear to be some kind of coarse granite. Compared with the enormous quantity of the erupted mass the stones are very few. Of pumice-stones both larger and smaller pieces were erupted. The larger pieces of

pumice are now most readily found caught in the branches of the trees. The largest found measured one foot in diameter; but these are exceptional, judging from the pumice found floating in the ocean. For miles and miles the surface is covered with a blanket of pumice-stone, entirely hiding the water from view.

The temperature of the projected sand seems to have been cold, at least when it reached the ground. The lowest vegetation immediately under the first deposited mass remains perfectly uninjured, and is yet fresh and green. In places where the rain has washed away the sand this vegetation, consisting of grass and tender leaves, is so little harmed that it begins growing when exposed to the light. It has not even been bleached. The sand could not, therefore, have been very hot when it reached the ground; but the fact that the stones thrown out appeared as shooting stars in the air sufficiently shows that the mass was intensely heated.

Besides these heavier particles of sand, stones, and ash there were enormous clouds of vapour ejected by the volcano, principally of steam mixed with sulphurous fumes. There was no eruption of fiery gases or directly poisonous fumes.

The later daily eruptions were confined to steam and gases, and at my departure from the volcano on December 4th no lava had been thrown out.

Loss and Injury caused by the Eruption.

Temporary Injury to Vegetation.—Within a district about twenty miles wide and seventy-five miles long all the trees lost their leaves and all the tender vegetation was injured. This destruction was due to the grinding effect of the falling sand and not to its temperature. In this vast district, which extended halfway down the coast to the ocean, not a green leaf could be seen when the clouds scattered sufficiently to allow a good view. Many of the trees had been split and killed by lightning; while nearly all had branches broken, and some were uprooted. The leaves of the Arabian coffee trees had dried up. The berries were dried, and had assumed a dark gray colour, long before they had arrived at maturity. These berries were still not entirely lost, but were being harvested as an inferior coffee. Where the fall of sand was less than two feet deep fewer leaves had been killed and more berries remained green. The Liberian coffee trees seemed to be uninjured, their berries and leaves remaining perfectly green, even in places where the native vegetation had been destroyed.

Where the fall of sand only amounted to five or six inches no

injury seems to have been caused. The actual loss of the coffee is calculated to have been about eight-tenths of the whole crop in the district devastated, or about one-half of the crop of the Pacific coast of Guatemala.

PERMANENT INJURY TO VEGETATION.—This injury cannot as yet be accurately judged. Within a radius of three miles from the crater every particle of vegetation appears to have been permanently killed. I am of the opinion that where the coffee trees are covered with over four feet of sand the plants will be permanently destroyed; while, where less than this amount has fallen, it will take the surviving plants from two to three years to recover their bearing capacity. Where, however, the fall has been as little as five or six inches it seems as if the trees may recover in two seasons.

As to the permanent injury done to the forest trees, nothing can be now said, except that wherever they are covered up to any great extent they will probably die. The area of destroyed forest is less than the area within which the coffee plants are destroyed. Already, a month after the eruption, the majority of the trees began to send out fresh leaves from uninjured branches; while the coffee shrubs, which had lost their branches, sent out fresh leaves from their main trunks.

INJURY TO ANIMAL LIFE.—Nearly all the birds over an enormous area seem to have been killed. After the first eruption birds could be seen everywhere on the roads in a dazed condition, running hither and thither, and easily caught by the hand. It is probably that all such starved and injured birds died. A month after the eruption the blackbirds had returned, and seemed as happy as before. They were probably the only birds which had sense enough to save themselves by flight. It is probable that mammalian life was destroyed to even a greater extent than the birds. At every step in the forest we were offended by the odour of dead animals buried under the sand. The world of insects seemed to be renewed. Butterflies and beetles were found in many places; while flies and mosquitoes were numerous. The large ants, called *zompopos*, had already began to dig their new canals, and we found them carrying up the underlying brown soil and placing it on the white sand five feet higher up.

Great numbers of cattle had been killed. Those that had not succumbed during the first few days had died afterwards from eating leaves and grass covered with sand or from drinking water mixed with mud.

Of human beings the loss was great, and it is probable that as many as 1,500 were killed, principally by falling roofs, or by lying down on the ground and thus being covered up. The majority of the men got drunk in order to "keep up their courage," I was told.* To this fact must be ascribed the greatest loss of life. Except in the immediate vicinity of the new crater nearly every human being could have saved himself by starting towards the coast at the first breaking out of the volcano.

INJURY TO THE SOIL.—In the vicinity of the crater the soil is covered by sixty feet of sand. All such land is irreparably destroyed. In places where the deposit only amounts to a few feet or a few inches the continued vegetation will soon form new top-layers of leaf mould. The newly-deposited sand is not likely to be able to produce surface crops until such mould is formed. This injury to the soil is more serious than any temporary injury done to the crops. Even in places where the coffee trees survive it is to be doubted if new shrubs can be made to grow in the new layers.

Another injury to the soil is found in the numerous gullies formed by the washing away of the sand. To cultivate such a soil will be very difficult and costly. Every inch of ground is covered with sand over a large territory. In a small village which had not been entirely destroyed some one calculated that there had fallen twenty thousand tons of sand for every man, woman, and child. And still in this place there were only nine inches of sand covering the ground.

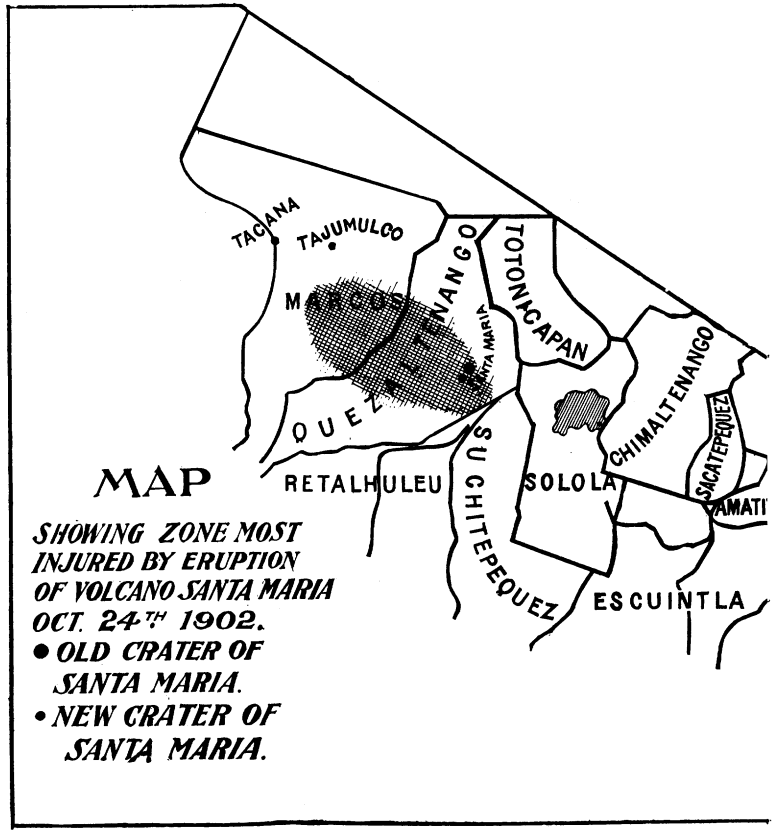
I was shown in several places ground which had been changed in colour by the deposited sand, and it was believed that such soil had been greatly injured in quality. Thus on the finca Felicidad the superintendent told me that his most fertile black soil had been turned red. We dug out such soil in various places; and though I had not examined it previously, I have every reason to credit the statement. But I had observed that the roads running through such black lands were always of a chocolate red, even in places where no sand had been deposited; and it seems probable that the change in the colour of the soil was due to some oxidation or other chemical action. The vegetation of this soil which had been changed to chocolate red was entirely uninjured by the overlying sand.

INJURY DONE TO BUILDINGS, ETC.—The injury done to buildings resulted principally from the caving-in of the roofs through the

* A statement more easily made than verified.—(*Ed. Bulletin.*)

accumulation of sand. It has been great, but it has been much overestimated. In Retalhuleu, for instance, the first reports were that almost every house had been destroyed, while in fact not a single house had caved in or been seriously injured.

INJURY TO THE LAND IN GENERAL.—Great injury has been done to the river-beds and river banks, as has already been stated. This injury is permanent; but it is lessened by the fact that the beds have



now been made larger, and future floods will be less destructive. One of the most serious results of the eruption is that for several leagues on each side of the port of Ocos the shore-line has subsided. About one hundred feet all along this coast has sunk down, and the waves now reach up to the very houses which before the eruption stood that distance away from the shore. This subsidence began after the earthquake of April 18th, but increased after the eruption. The costly iron pier for the landing of freight was

broken in two by the earthquake, and the injury done then has since increased. The lower part of the River Ocos changed its course, and the village is now threatened also from that side.

COMPARATIVE INJURY OF THE VARIOUS ZONES IN THE DEVASTATED DISTRICT.—The part of the coast especially injured by the eruption is generally known to outsiders as the Costa Cuca. The inhabitants, however, divide this coast into several distinct zones, separated by rivers or places not well suited to the cultivation of coffee. These zones have been variously affected by the eruption, as follows:

Xolhuitz —About six leagues square. The largest part of the coffee and sugar-cane crop is destroyed.

Costa Cuca.—About 12 leagues by 6 leagues. Totally destroyed crops.

Chuva.—About 8 leagues by 4. Crops almost totally destroyed.

Costa Grande.—About 8 leagues by 3. Crops partly ruined.

Tumbador.—About 8 leagues by 3. Only slightly injured.

Costa Pamachan.—About 6 leagues by 8. Crops not injured.

RED SUNSETS.

Before the eruption of Santa Maria no such red sunsets had been seen anywhere. But immediately after the eruption red or blood red evening skies were observed in the belt covered with ashes. These sunsets did not reach Guatemala City for one month after the eruption, the winds probably carrying the ashes the other way. When I passed along the Pacific coast in the middle of December the red sunsets did not appear higher up than Acapulco. Several weeks later they had reached the coast of California, but were of much less intensity than in Guatemala. They seemed to decrease in intensity as they proceeded northwards.

PREHISTORIC ERUPTIONS OF SAND AND ASH.

It is of considerable interest to inquire into the effects caused by former eruptions of the Guatemala volcanoes, and if, perchance, any one of them resembled the eruption of Santa Maria. I made a special point to study this matter wherever opportunity offered.

As already noted, the eruptions of the Guatemala volcanoes since the earliest times have been of three kinds. The first eruptions were those of basaltic rocks. These lava-flows are yet, to a great extent, in evidence, their topsoil, as well as their alluvial deposits surrounding them, having been washed away long before the present alluvium of the coast was formed.

The second, andesite volcanoes, seem never to have produced any lava-flow of extraordinary dimensions. At least in modern times all lava-flows have been small and ceased not very far from the craters. The third class of eruptions consisted of sand and ash of nearly the same quality as those of the last eruption. From below Pacaya to the northern end of Tacaná the slope of the coast is mainly made up of deposits of white sand, covered by layers of various coloured humus soils, varying in depth from a few feet to a hundred feet. On the coast side there is little opportunity to study these deposits, but to the interior of the cordillera the numerous and deep barrancas offer excellent profiles for study. All the volcanoes, with the possible exception of Pacaya, have in prehistoric times thrown out immense quantities of ash and sand, principally made up of finely-ground pumice-stone. These deposits reach as far northwards as Salamá, Rabinal, Huehuetenango, etc., and seem to have been carried there from the Pacific coast volcanoes yet in existence. The greatest deposits, both as regards extent and thickness, are those found north of the Volcan de Agua. On the way from Chimaltenango to Mexico we pass several deep barrancas in which the strata of volcanic sand and ash alternate with strata of chocolate-coloured loams. I have counted eight or nine such alternating layers. Generally, the layer of chocolate loam is from one to six feet deep; while the white sand and ash layers are from ten to twenty-five feet deep. But in a barranca near Santiago, Sacatepequez one of these layers of erupted sand measured about one hundred and fifty feet, and immediately below it was seen a stratum of chocolate-coloured soil about six feet thick. It will thus be seen that at certain intervals eruptions of sand and ash have taken place since the first volcanic outbreaks, and that these eruptions have been succeeded by periods during which vegetation regained its hold and was able to form a humus of a chocolate colour from one foot to ten feet in thickness. The most recent of these, the largest deposits of sand, seems to have come from Agua. The uppermost erupted layer from this volcano, as observed on the road from Antigua to Guatemala City, averages in depth about four feet. Above this layer is deposited a stratum of humus about three feet thick. If we could calculate the time it takes in this region to form a certain layer of soil it would, of course, be possible to determine the years gone by since the last eruption of Agua. This may have occurred three or four thousand years ago, the formation of humus in this region being very slow, on account of the long dry season and the poor vegetation generally so far inland.